Lawrence Livermore National Laboratory

Dynamic Strength Experiments

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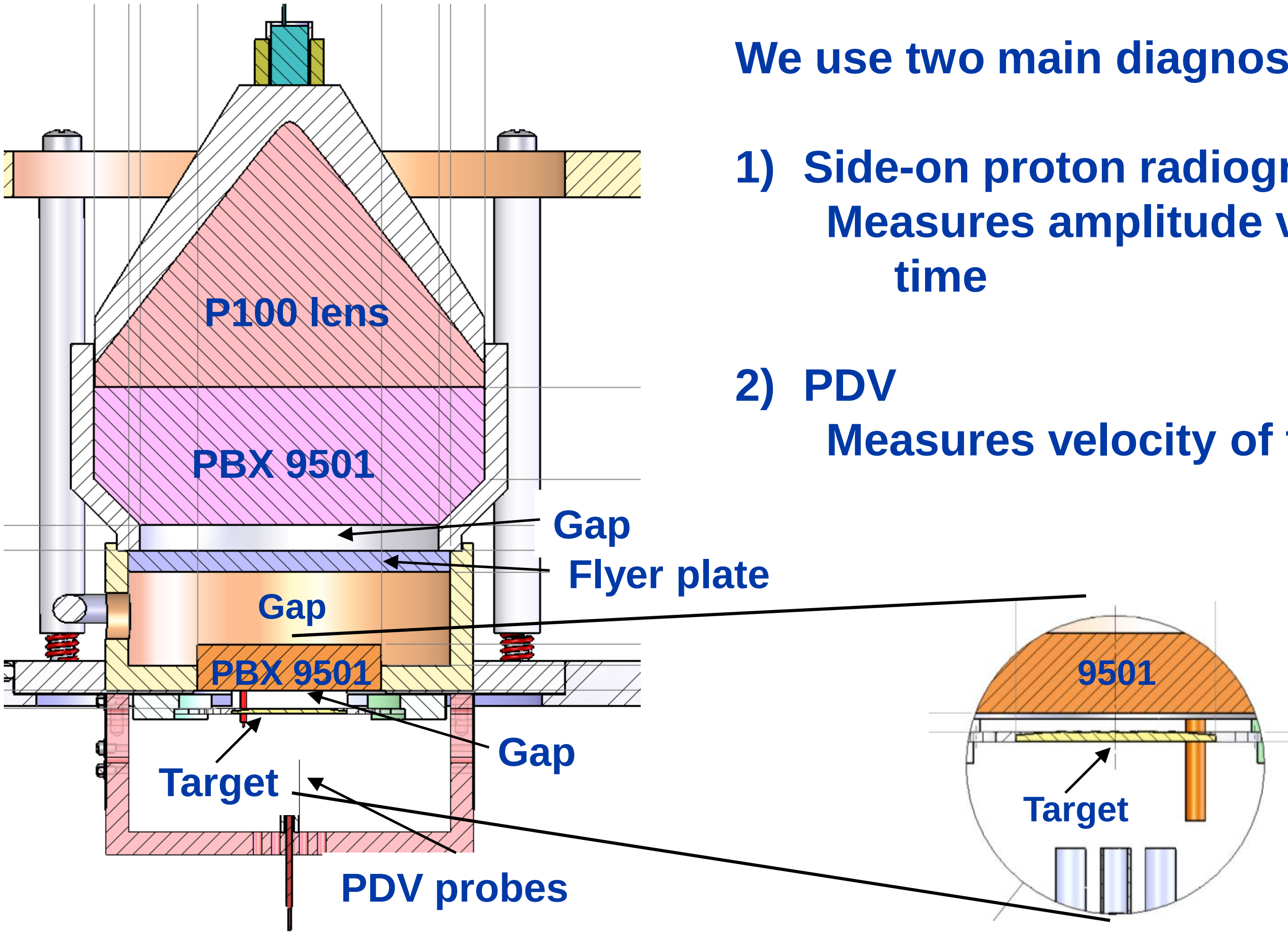
We use solid Rayleigh-Taylor instability growth to study strength models

- Strength experiments can be done at different pressures, strains and strain rates
  - Hopi-bar: $P = 0$, $\varepsilon \sim 0.3-0.5$, $\dot{\varepsilon} \sim 10^4$ s^{-1}
  - HE-driven Barnes experiments: P ~ 0.5 Mbar, $\varepsilon \sim 0.5-3$, $\dot{\varepsilon} \sim 10^5 - 10^6$ s^{-1}
  - Laser-driven Barnes experiments: P ~ 0.2 – 10 Mbar, $\varepsilon \sim 3$, $\dot{\varepsilon} \sim 10^6 - 10^7$ s^{-1}
- HE experiments at pRad on vanadium and tantalum complement on-going work on the Omega and NIF lasers.
- Preliminary analysis of the pRad data suggests we can measure material strength of Ta to better than 15%

We use a two stage HE drive to accelerate isentropically a solid rippled metal target

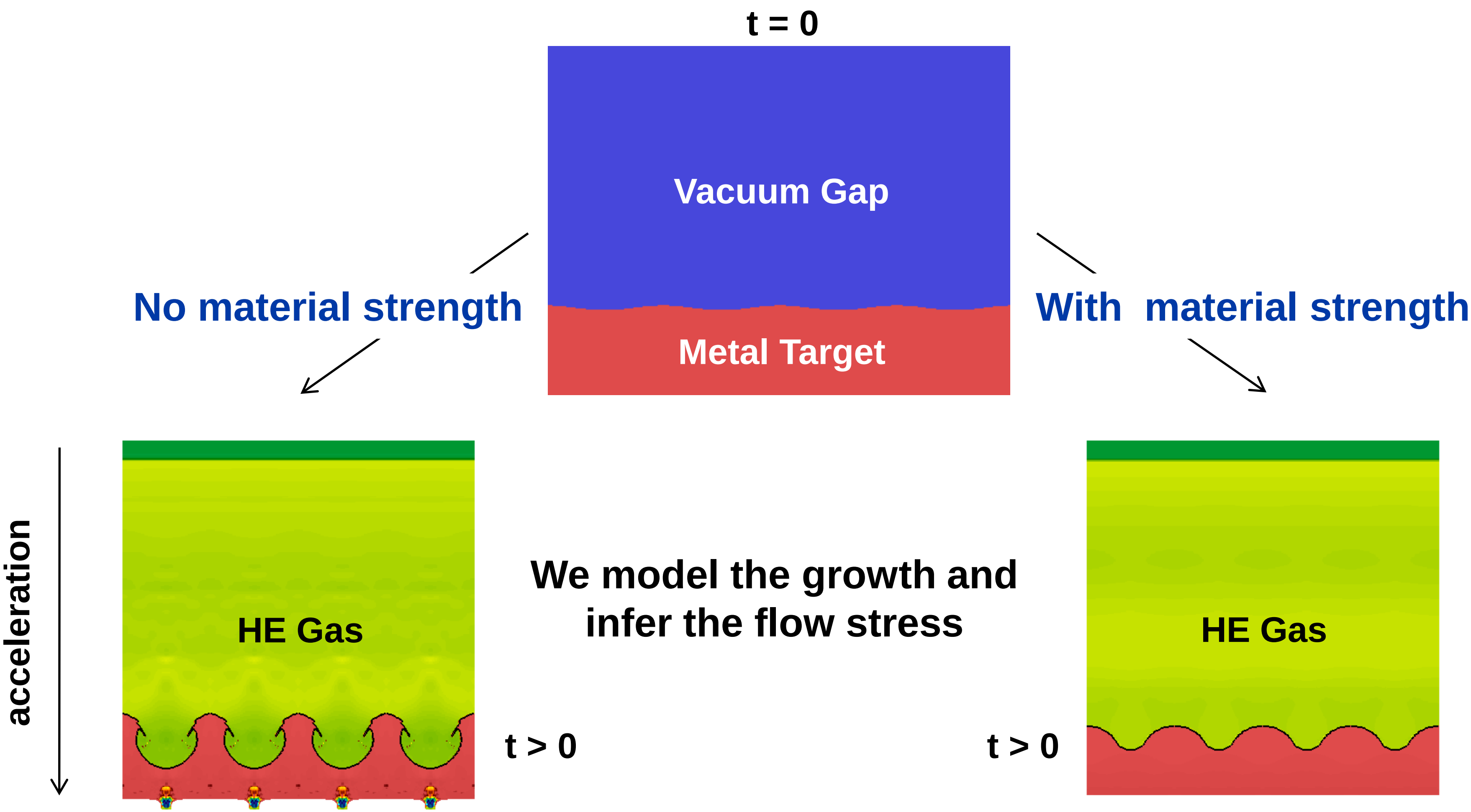


We use two main diagnostics:

1) **Side-on proton radiography**
   Measures amplitude vs. time

2) **PDV**
   Measures velocity of target

Strength inhibits Rayleigh-Taylor growth



We studied vanadium and tantalum under different drive conditions

Different shots explore the effects of variations in *gap size, wavelength* and *initial amplitude*

Shot	Material	Gap (mm)	λ (mm)	η_0 (mm)	P_{peak} (kbar)	$d\varepsilon/dt$ (s^{-1})
292	V	3.0	3.0	0.04	520	9×10^4
293	V	4.5	3.0	0.03	460	5×10^4
299	V	4.5	3.0	0.04	470	6×10^4
291	Ta	3.0	2.0	0.04	570	4×10^5
297	**Ta**	**6.0**	**2.0**	**0.04**	**470**	$\mathbf{2 \times 10^5}$
298	Ta	4.5	2.0	0.04	510	3×10^5

We explore Shot 297 in detail here

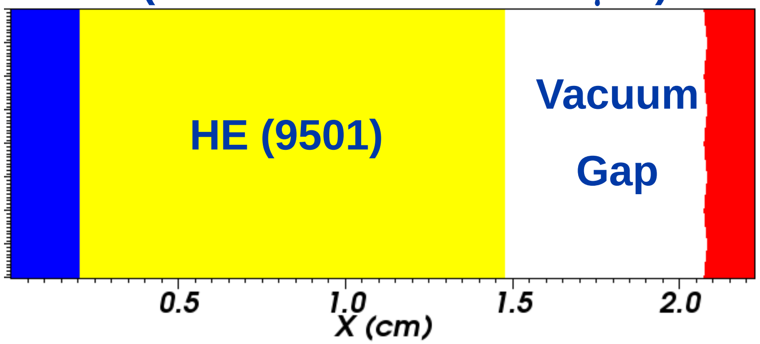
We use independent flyer plate data to model the drive

Material plot of problem set up at t = 0

(mesh resolution = 25 μm)

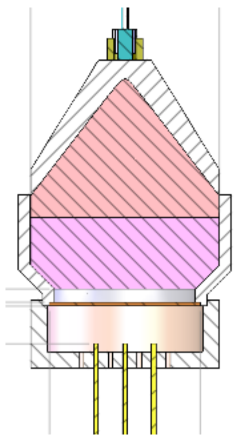
Stainless Steel

Flyer plate



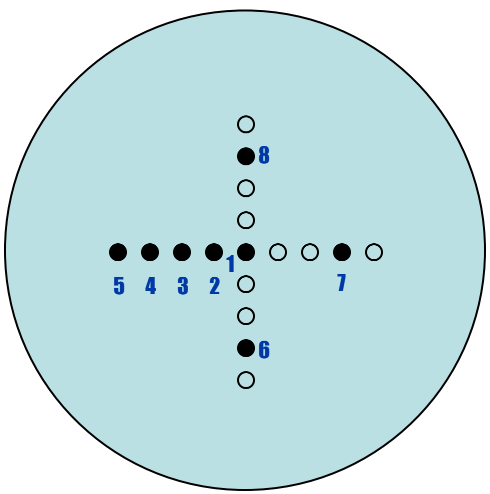
Metal Sample

(V or Ta)



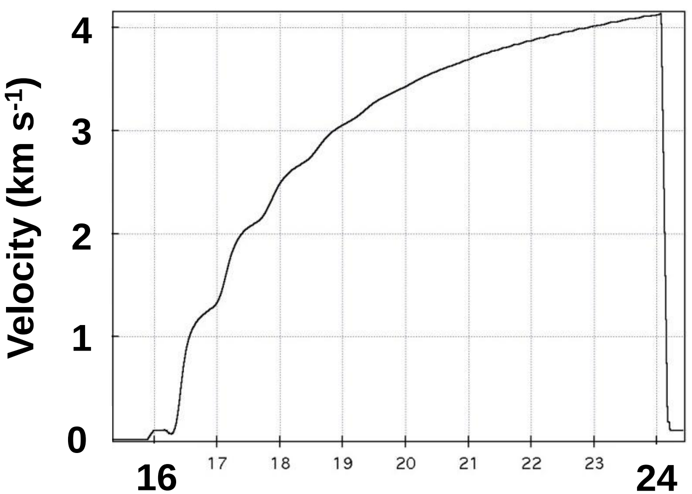
Set up to measure

flyer plate motion

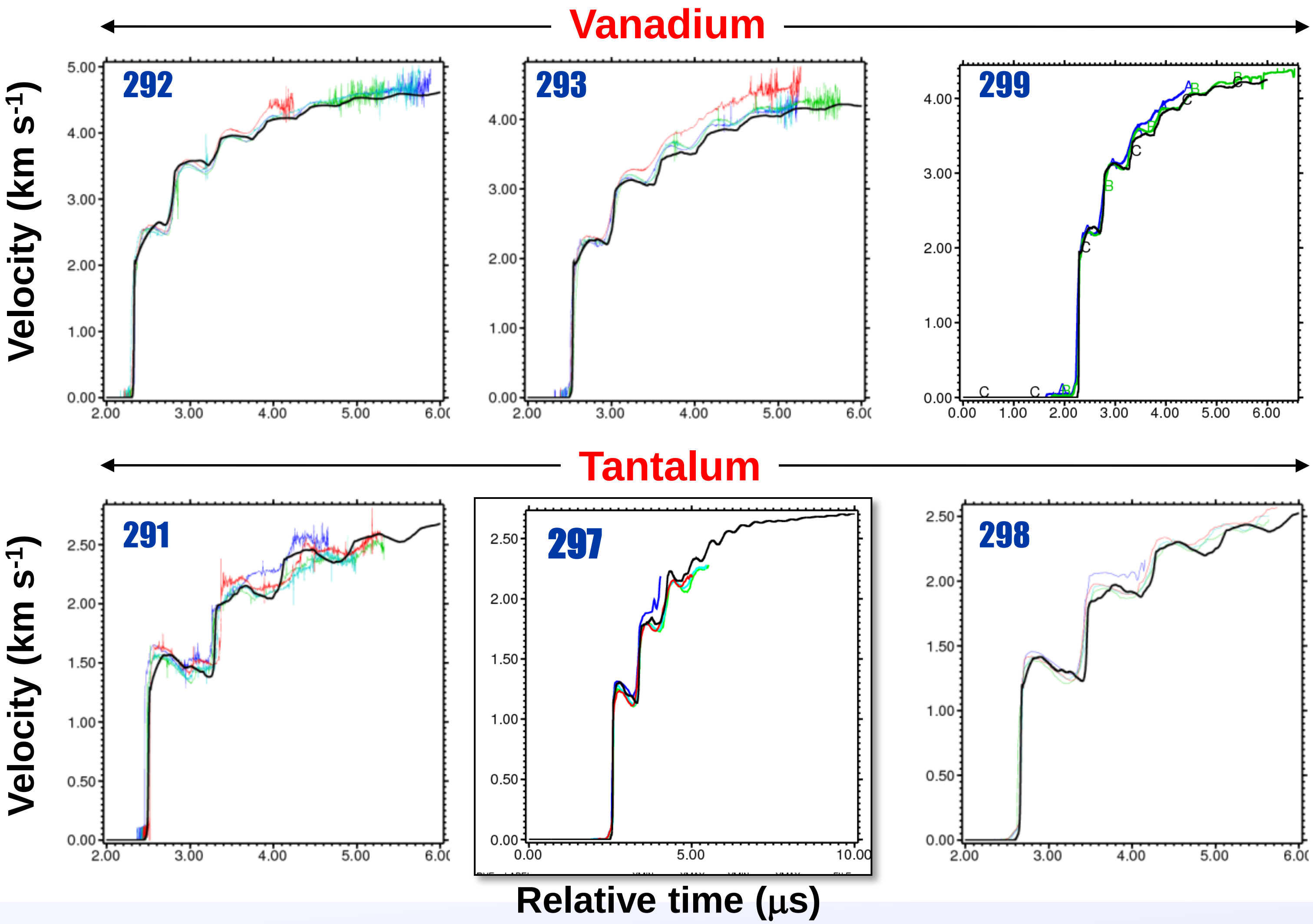


PDV Probe Layout

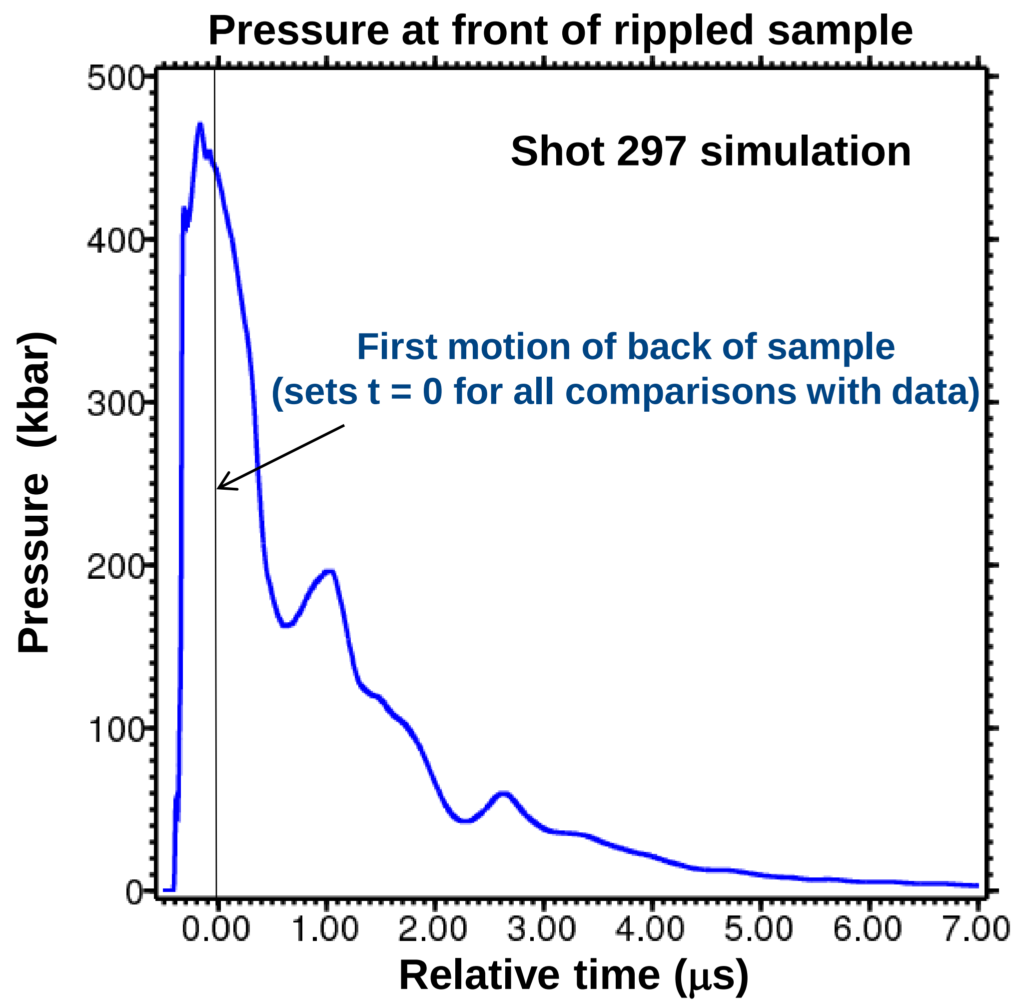
Flyer plate velocity



The same JWL++ parameters fit the drive data from all the shots very well

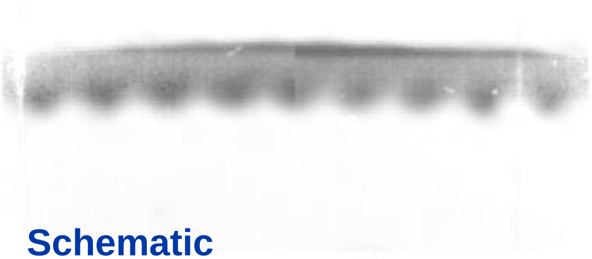


The loading profile is dynamic, with the peak pressure occurring prior to release

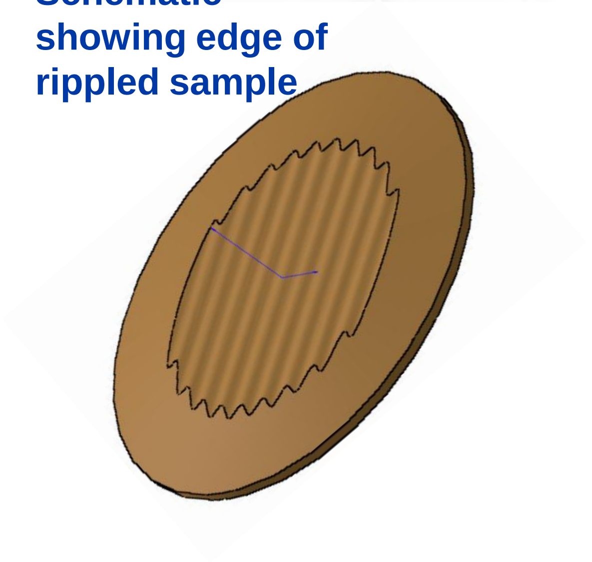


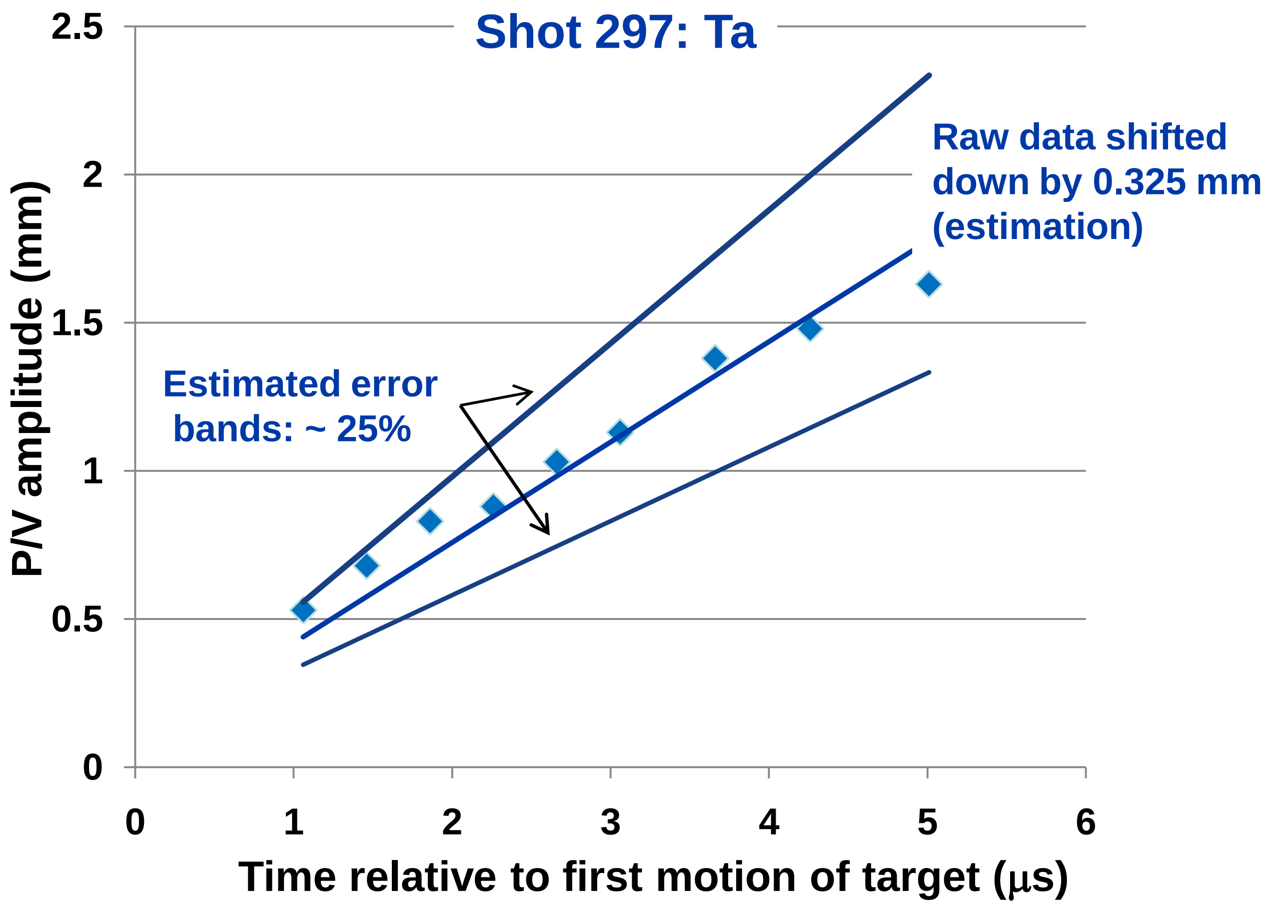
The tantalum data have large uncertainties in the growth due to the edge of the sample blocking the view of the troughs

"edge-subtracted" radiograph at t > 0



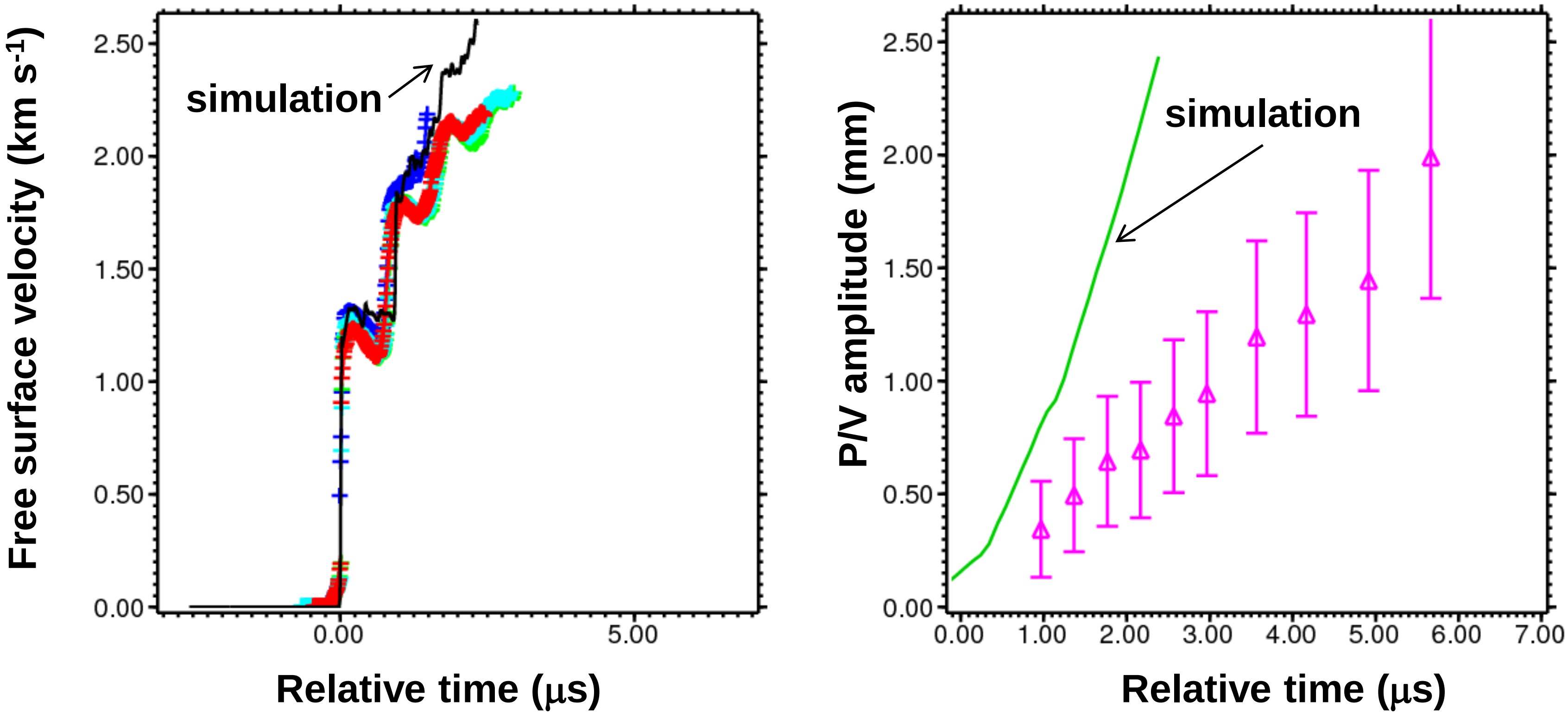
Schematic showing edge of rippled sample





Comparison with classical RT simulations demonstrates material strength is limiting the growth

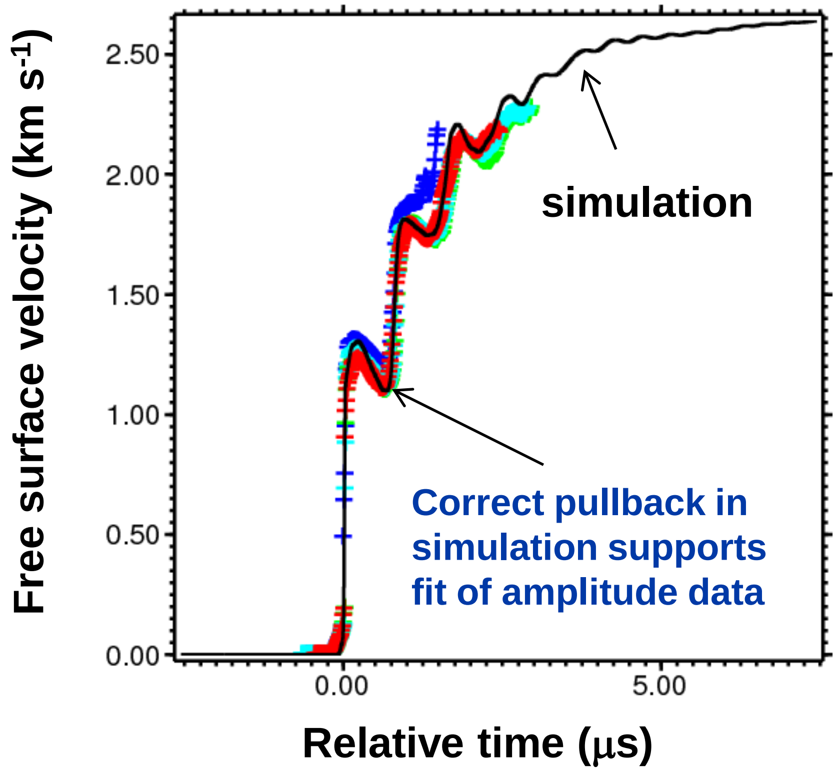
No material strength case

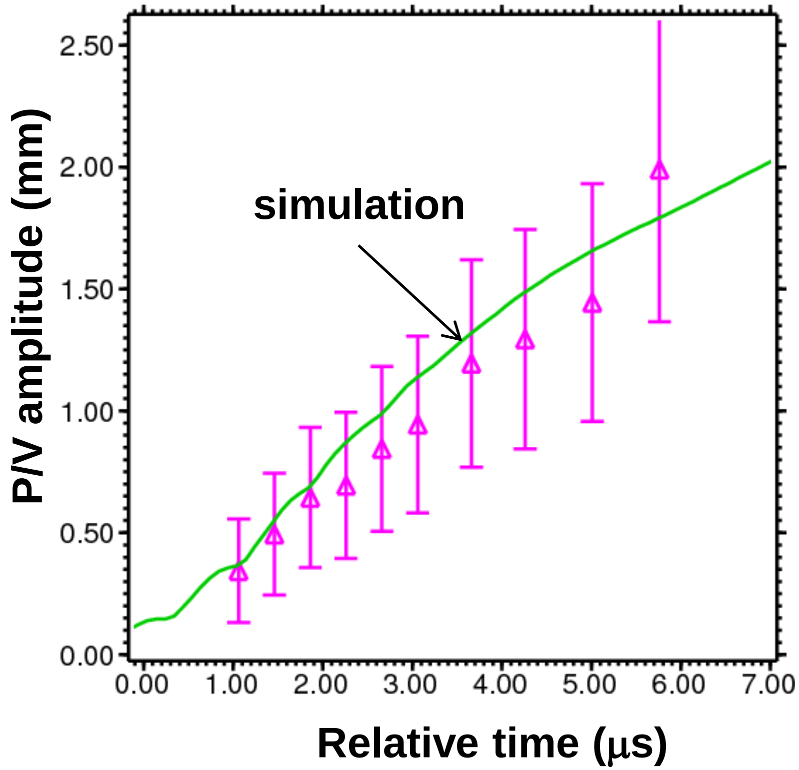


The lack of pullback in the velocity simulation compared with the data also indicates strength

The nominal PTW parameters fit both the velocity and amplitude data well

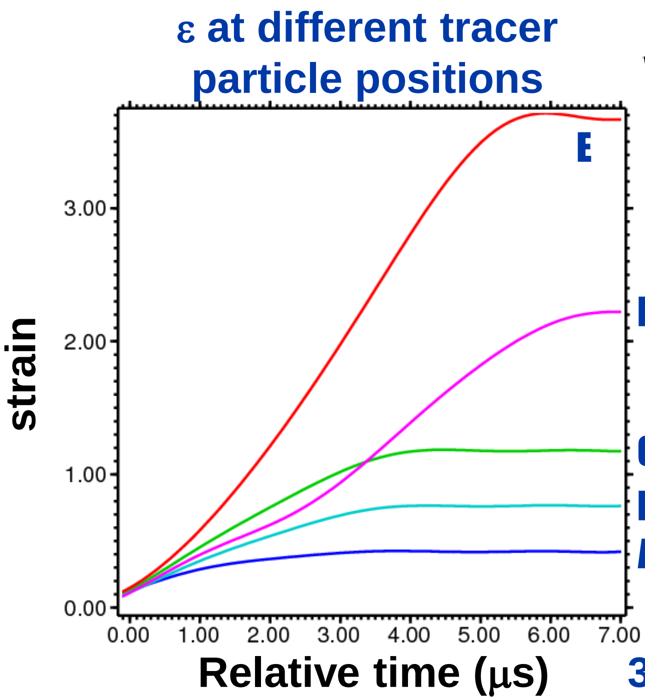
pRad shot 297 simulated with PTW strength model

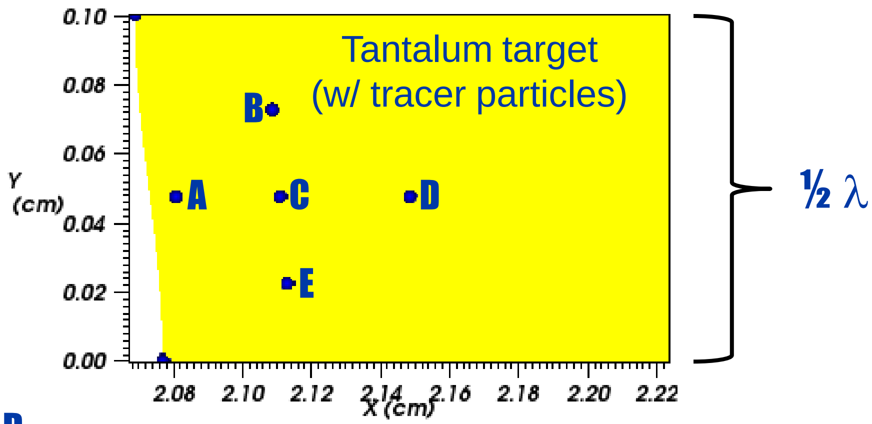


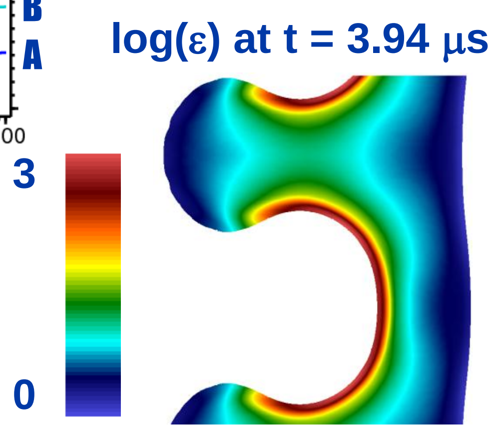


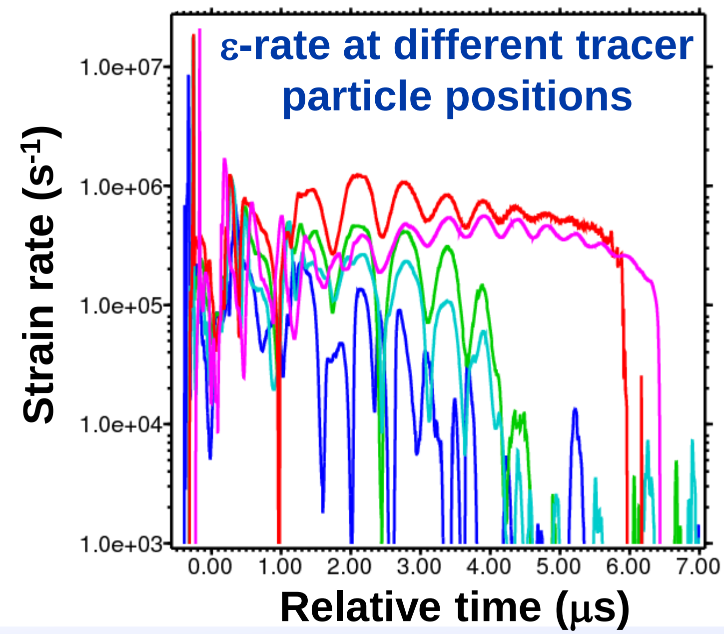
The inferred peak flow stress is 11.6 kbar for Ta at an applied stress of 470 kbar and a strain rate of ~2.5 x 10^5 s^{-1}

The strains and strain rates vary with time and space

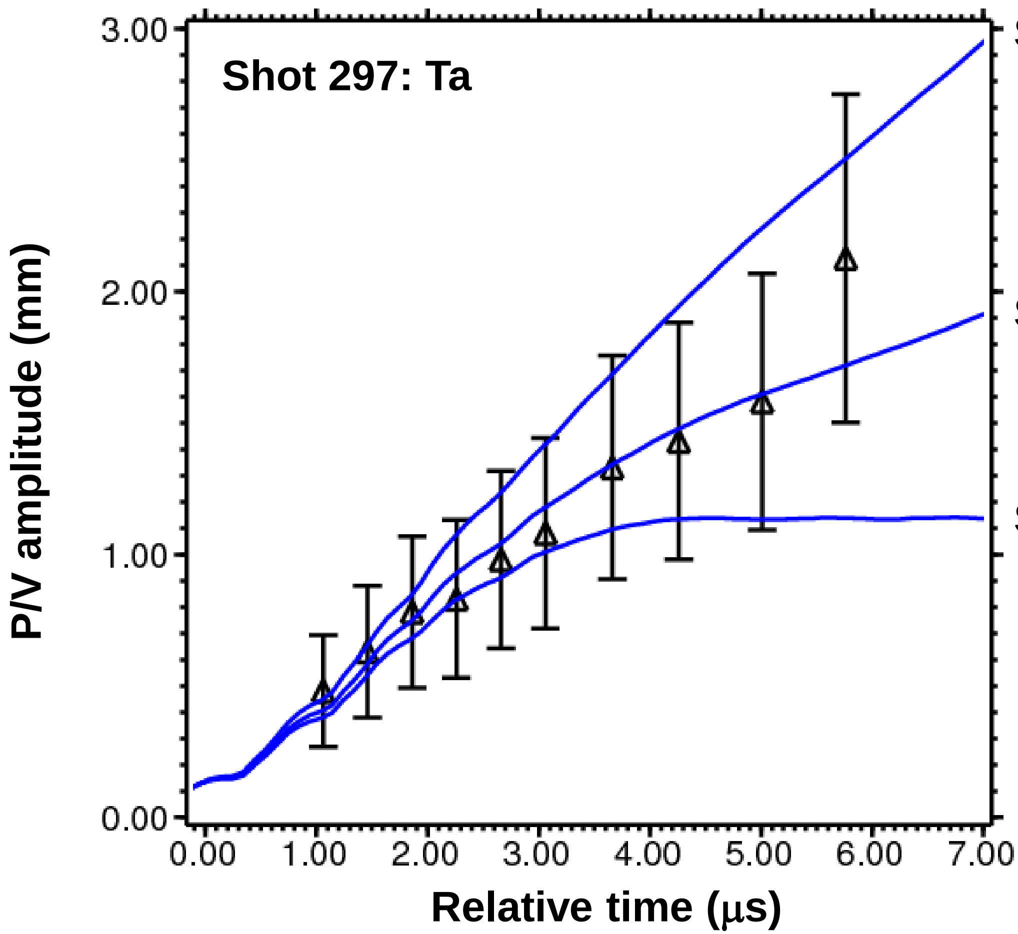








We estimate the peak flow stress to be 12±1.5 kbar based on the SG model fits to the error bars



SG: $0.80 \times Y_0$; σ_{peak} = 10.5 kbar

SG: $0.92 \times Y_0$; σ_{peak} = 12.0 kbar

SG: $1.0 \times Y_0$; σ_{peak} = 13.0 kbar

The peak flow stress for the PTW model is 11.6 kbar

Conclusions

- HE driven Barnes experiments on vanadium and tantalum provide a platform for studying material strength at *P* ~ 500 kbar and strain rates ~ 10^5 s^{-1}
- Our HE model captures the drive behavior very well
- The error bars on shot 297 due to incomplete edge extraction dominate the error in the strength measurement
- Nominal PTW parameters for Ta fit the growth well
- Using the Steinberg-Guinan model, we estimate the peak flow stress for the Ta shot 297 to be 12 ± 1.5 kbar, consistent with the PTW interpretation
- These results will aid in the design and interpretation of laser driven Barnes experiments